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Spaceport Engineering and Technology Directorate
Labs and Testbeds Division
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KSC-MSL-0488-2001

SUBJECT: Failure Analysis of a Fuel Cell Power Reactant Supply and Distribution (PRSD) Liquid Hydrogen (LH_2) Relief Valve P/N K5120T-3MP-285

CUSTOMER: Al Staveland/USA/USK-126

1.0 ABSTRACT

An LH_2 relief valve from the PRSD was discovered cracked and was submitted for failure analysis. The valve was reportedly in service for approximately four years. Fractographic and metallographic evidence indicated that the valve failed due to stress corrosion cracking (SCC). The valve body had a composition similar to 303 stainless steel (UNS S30300). Free-machining austenitic stainless steel does not have a high resistance to SCC, per MSFC-STD-3029, and is not recommended for use at KSC.

2.0 FOREWORD

An LH_2 relief valve from the PRSD was discovered cracked and was submitted for failure analysis. The customer reported that the valve had been in service approximately four years and was to be composed of 303 stainless steel.

3.0 PROCEDURES AND RESULTS

3.1 The valve is shown as-received in Figure 1. A longitudinal crack was evident in the valve body (Figure 2).

3.2 Macroscopic examination of the valve body revealed the presence of corrosion products on the fracture surface (Figure 3). The fracture surface appeared “woody,” typical of SCC.

3.3 Examination of the fractures via scanning electron microscope (SEM) revealed “mud cracking” of corrosion products, as well as transgranular fracture features (Figure 4), both typical of SCC. A laboratory-induced overload exemplar (Figure 5) exhibited ductile fracture features;

manganese-sulfide stringers (verified via energy dispersive X-Ray spectroscopy [EDX/S]) were also observed. EDX/S analysis also revealed the presence of chlorides on the fracture surface.

3.4 Chemical analysis via inductively coupled argon plasma and combustion techniques indicated that the valve body had a composition similar to that of 303 austenitic stainless steel.

3.5 Metallographic examination of the valve revealed secondary cracking emanating from the primary transgranular crack (Figure 6). Stringers were evident throughout the sample, with some exposed to the surface. Converted microhardness measurements averaged approximately 23 Rockwell C scale.

4.0 CONCLUSION

The valve was composed of 303 stainless steel and failed due to SCC. Three factors are required for SCC to occur: a corrosive environment, a source of sustained tensile stress, and a susceptible material. The environment at KSC is highly corrosive to many materials, satisfying the first criterion for SCC. The stresses developed during service, as well as residual stresses from manufacture, would satisfy the second requirement for SCC. 303 austenitic stainless steel is considered to have low resistance to SCC (per MSFC-STD-3029), meeting the third prerequisite for SCC.

5.0 RECOMMENDATIONS

The use of 303 stainless steel is not recommended at KSC. Alternate materials, such as those listed in Table 1 of MSF-STD-3029, could provide better resistance to SCC.

EQUIPMENT: SEM S/N MP1770061
EDX S/N 3552
Metallograph S/N 237386
Microhardness Tester S/N B-D58073

RELATED DOCUMENTATION: MSFC-STD-3029
KSC-MSL-0488-2001-01

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Figure 1

As-Received valve. Arrow indicates crack.

Figure 2

As-Received valve body. Magnification: 3X

Figure 3

Macrographic view of the fracture surface from the valve. Note the “woody” appearance of the fracture surface (between the arrows) and the presence of corrosion products. Magnification: 5X

Figure 4

SEM micrograph of “mud cracking” of corrosion products surrounding a portion of the fracture surface. Magnification: 430X

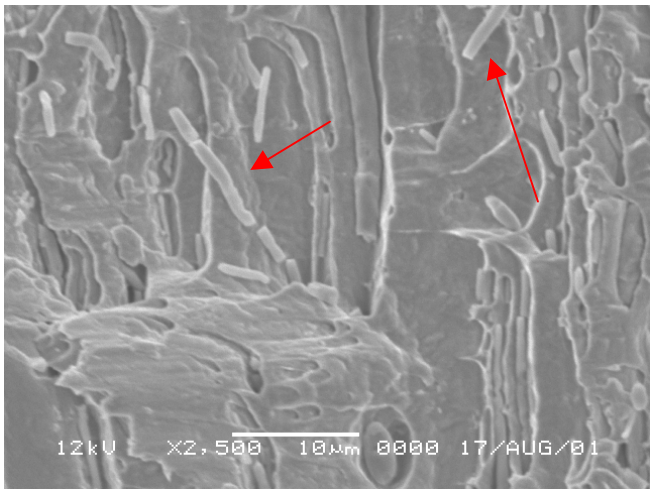

Figure 5
SEM micrograph of laboratory-induced overload exemplar, showing stringers (indicated with arrows). Magnification: 2,500X

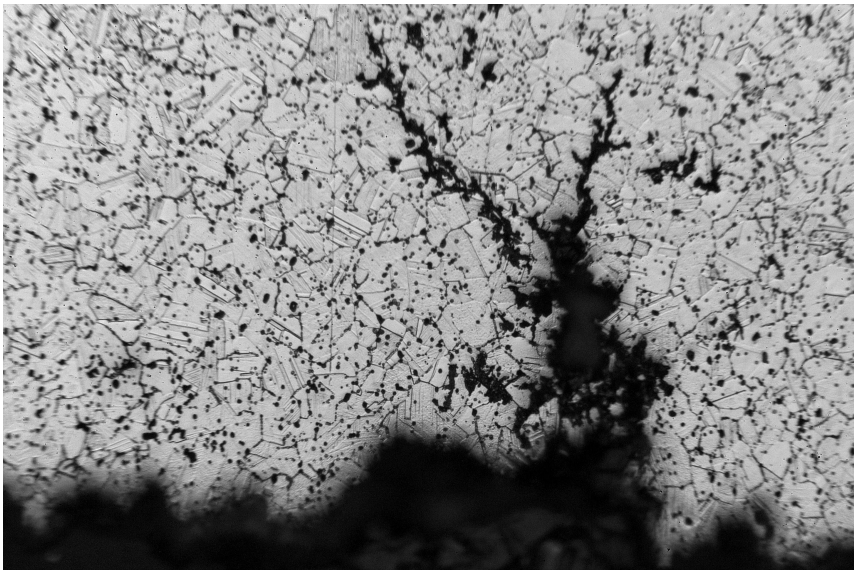

Figure 6

Micrograph of a cross-section of the valve body displaying secondary crack branching. Etchant: 10% Oxalic Acid (electrolytic). Magnification: 150X